N C E P

D O W N S C A L I N G,
Probabilities (confidence?)
& Analysis of Record

Geoff DiMego

21 January 2004

where the nation's climate and weather services begin

T O P I C S

- Rolling update of
  - October 21 presentation in SRH - Dallas / Fort Worth, Texas
  - December 19 presentation to Jack Hayes
- Probabilities (confidence factor?)
- Analysis of Record

N C E P

NCEP Proposal for: Downscaling Model Grids for NDFD Out To 8 Days

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where the nation's climate and weather services begin

Purpose of Downscaling

- Extend the information content of coarse model prediction fields to finer scales that reflect the influence of detailed local effects such as terrain and or land-surface

- Initialization of NDFD especially at day 8

- Analysis of Record needed to verify NDFD

CHRONOLOGY

- Request from Glahn & Livesey for Analysis of Record to verify NDFD (unofficial & unfunded) -- Oct 2002

- Request from Jack Hayes/Brad Colman for 1-page proposals for downscaling approaches:
  - 25 year 2 km climo of sensible wx by downscaling 25 year 32 km NARR used as observed basis for MOS/Neural Net development to downscale NARR & GR forecasts to 2 km
  - Local model with nudging
  - Anomaly techniques (Lord & Toth)

- First approach (preferred) had long timeline (2+ yrs)$$

- Brad Colman came to EMC based on strong desire for something to help forecasters with NDFD in the short term -- led to idea to downscale GFS guidance using Eta extension to 8 days

Relevance to NDFD

- Immediate need of the NWS Field is for high res grids to initialize GFE/IFPS/NDFD especially at day 8:

- High resolution grids of at least 5 km with a preference for 2.5 km

- Grids with uniform content out to day 8 at least once per day (currently using MRF grids which will be replaced by 4/day GFS so demand may be for more than just once per day)

- NDFD parameters (sensible weather) but preferably full 3-D grids to populate GFE / IFPS in anticipation of improving SMART TOOLS

Extension to 8 Days: Background

- Original request asked for a single 24 hour Eta-12 forecast cold-started from 6.5 or 7 day GFS forecast (would have major spin-up problems)
- Next considered an extension from 60 hr for small (1/6th) domain to be run in place of 06z extension (NCEP Dir ruled out option to change current suite)
- EMC offered to compress schedule by pushing primary Eta run from 0-60 hr to 0-84 hr (freeing up slot to do 84-192 hr) when computer was upgraded
- Colman reiterated immediate need of NWS field
- EMC relented and proposed to compress schedule & put in 84-192hr extension on current computer
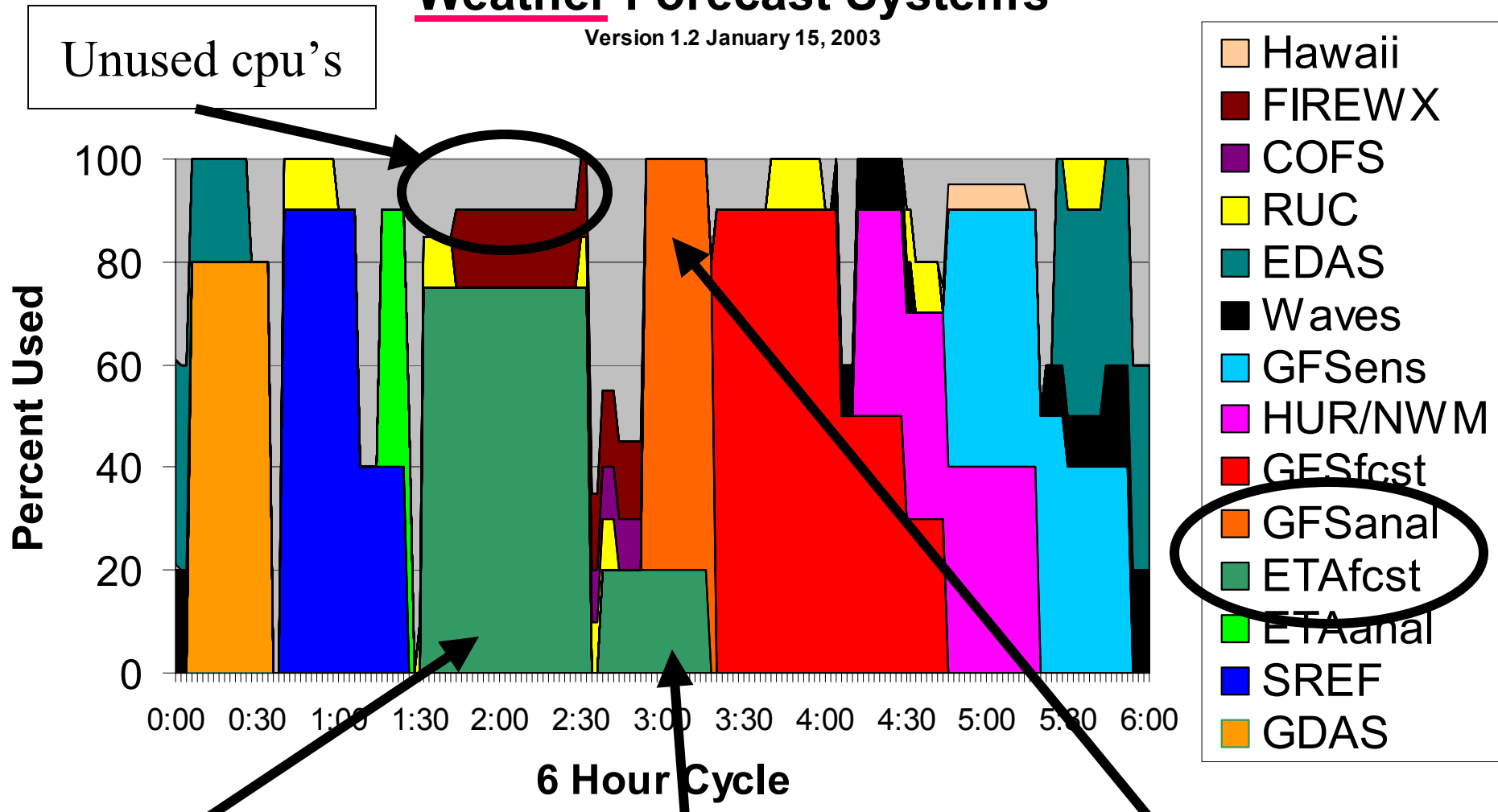
Extension to 8 Days: Proposal

- Currently run Eta-12 in 2 pieces:
  - Large block of machine to make 0-60 hr fcst
  - Small block of machine to make 60-84 hr extension
- Proposal is to:
  - Make first block bigger to make 84 hr fcst in same time window as 60 hr is taking now (NCO must verify availability of processors before NCEP can commit)
  - Use small block (no change in cpu resource) to run 4.5 day (84-192 hr) extension for small domain (1/4.5=2/9th)
- Four slots would be made available:
  - Run CONUS domain (2/9th) at 06z &18z extending the 00z & 12z GFS
  - Run OCONUS domains for AK (1/7th), HI (1/25th) & PR (1/25th) at 00z &12z extending the 18z & 06z GFS

Wx Production Suite Made Up of Four Uniform Cycles per Day

Proposed NCEP Production Suite
Weather Forecast Systems
Version 1.2 January 15, 2003

Unused cpu's

Large block Eta 0-60hr

Small block Eta 60-84hr

GFS analysis

Legend:
- Hawaii
- FIREWX
- COFS
- RUC
- EDAS
- Waves
- GFSens
- HUR/NWM
- GESfcst
- GFSanal
- ETAfcst
- ETAanal
- SREF
- GDAS

Percent Used

6 Hour Cycle

Reduced Eta Domains Allowing 5- or 6-day Extension in Same Slot as Current 1-day Extension on Full Domain
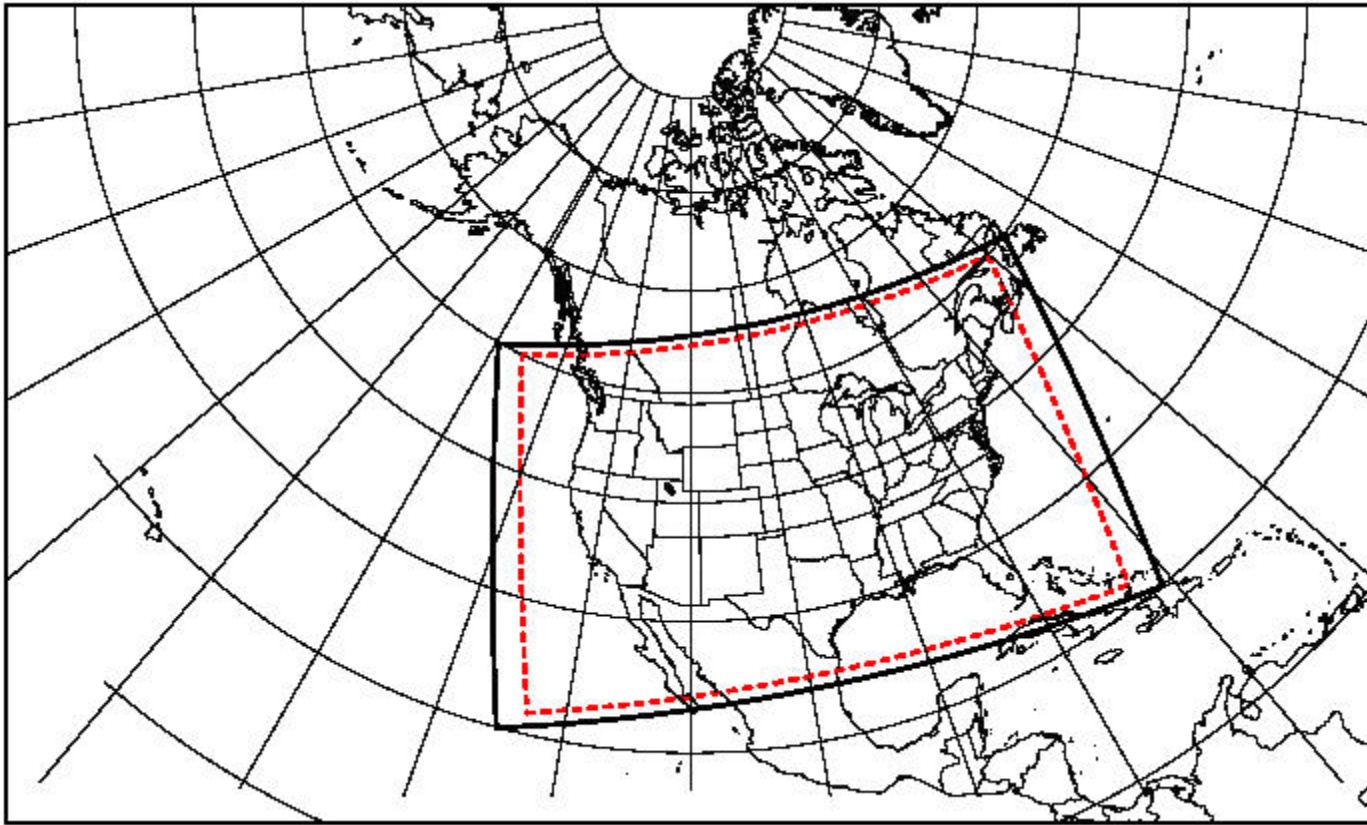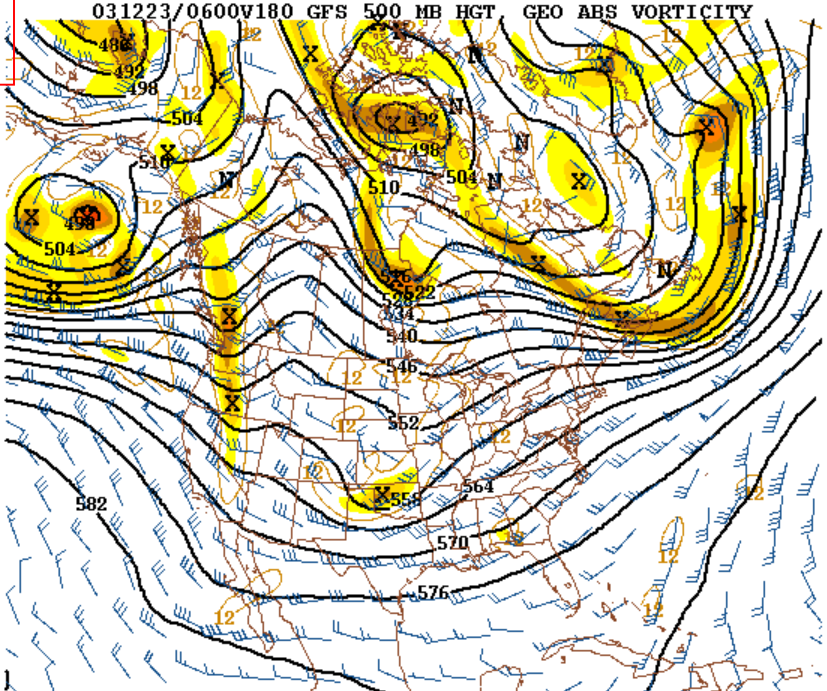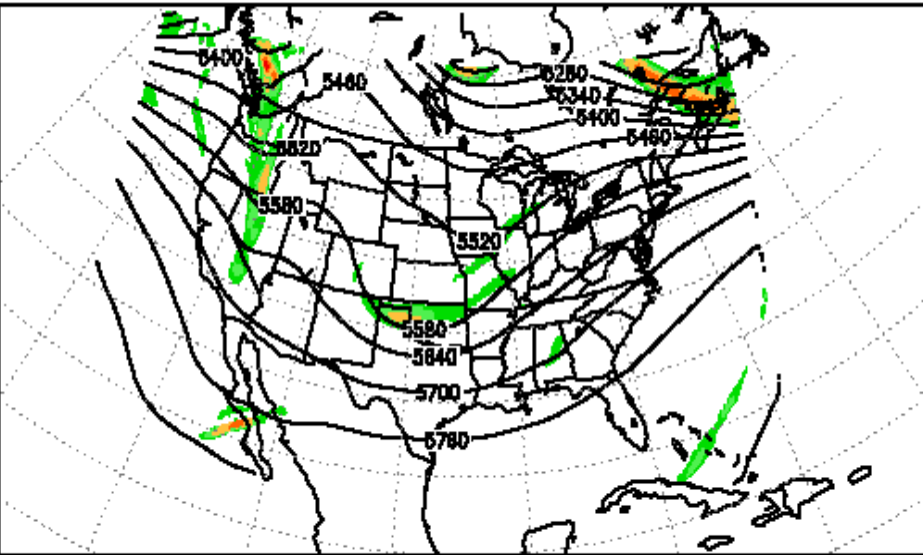

Domain could be a little larger since we only need to extend 4.5 days so we only need to reduce domain to 2/9th

Extension to 8 Days: Feasibility

- Eta extension will produce the desired effect of downscaling the GFS solution because the GFS synoptic scale forecast will dominate the Eta solution in the interior through the effects of the lateral boundary conditions especially for this small a domain and for this long of a prediction

- EMC's Eric Rogers built and demonstrated this capability with interior results quite similar to GFS forecast used for lateral boundaries

CONUS Test of Eta Extension of GFS

500MB Z-VORT ETA 174H FCST VALID 06Z 23 DEC 2003

031223/0600V180 GFS 500 MB HGT, GEO ABS VORTICITY

12/15/2003 18UTC 180HR FCST VALID TUE 12/23/2003 06UTC NCEP/NWS/NOAA

SLP ETA 174H FCST VALID 06Z 23 DEC 2003

031223/0600V180 GFS MSLP, PRECIP, 1000-500 MB THICKNESS

12/15/2003 18UTC 180HR FCST VALID TUE 12/23/2003 06UTC NCEP/NWS/NOAA

Product Generation

- "Downscale" 12 km Eta grids centrally using SMART INIT
  - Take advantage of huge volume of full 3-D Eta-12 grids available centrally
  - Produce much smaller volume of 5 km NDFD parameter grids which are 2-D sensible weather fields
- EMC concerned about running AWIPS software on IBM supercomputer platform
- NCO concerned about generation of AWIPS grids (no NetCDF expertise at NCEP)

Product Distribution

- Can't be decided by NCEP – must be worked from NWS/HQ & CIO
- Possibilities for product distribution include:
  - Distribute 5 km NDFD grids to NWS Regional HQ using WAN or Dark-Fiber
  - Distribute from Regional HQ to WFO using existing WAN which was recently upgraded
  - These would take advantage of the two-way comm's setup for collecting Level II 88D data which use only one direction (to Silver Spring) of a two-way capability
- NCO is concerned about overloading comm's & TOC processing capability
- NCEP is concerned about getting locked into doing this extension for perpetuity

Exit Strategy

- Declare this to be Experimental from the start
- Interrupt experiment when either of the following occurs:
  - Proper downscaling tool is developed for WFOs
  - Operational GFS analysis requirements expand beyond computer growth to accommodate them and small block for extension must be eliminated

Steps to Implementation

- NCO to validate strategy in general and verify availability of processors in particular ✔
- ~~Porting of SMART INIT to NCEP's IBM~~
- Precise definition of products ~~& their form~~
  - ~~NetCDF not supported and delta fields not liked by WFO's~~
- Assurance that MIC's embrace this strategy and the field can/will use the resulting guidance grids ✔
- Resolve exact distribution / comm's path

NCEP Concerns

- Commitment to develop proper downscaling and AoR capabilities must be made at the same time – essential for exit strategy

- Recognition that NDFD is still experimental and final Ops Concept has not yet been finalized

- Scientific basis for NDFD out to day 8 at high resolution & frequency is still being questioned

- Other IWT's pursuing non-complimentary solutions to NDFD initialization problem

- Comm's & computers are already filled to stress point

- Time window for Operational Eta (and its room for growth) will shrink again (Fire Wx took 15% in 2002)

- Eta / WRF development may be impacted

N
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Implementation of Eight-Day Eta for IFPS Support:

An NCEP Perspective

Dr. Louis Uccellini

Director, NCEP

December 19, 2003

WHERE AMERICA'S CLIMATE AND WEATHER SERVICES BEGIN

Requirements Presented by IWT

- Output grids from NCEP
  - 12km Eta grids in GRIB Format
  - Six-hour increments from 84-192 hours
  - 36 surface and boundary layer parameter plus currently unknown amount of pressure level parameters per forecast increment

- Product availability
  - Preliminary estimate – Eight-day forecast from 06 UTC Eta cycle available prior to 18 UTC NDFD cutoff time
  - Final timeliness requirement pending

IWT Proposed Response

- Regional headquarters pull 12 km Meso Eta grids from TOC FTP server and distribute to WFOs via regional WAN

- 12 km grids downscaled to 5 km in the Field
  - Downscaling software to be developed outside of NCEP using AWIPS Smartinit tools

- Grids inserted into IFPS through LDM at WFO
  - Backdoor dataflow method into AWIPS

Impacts to NCEP and Customers

- Large IBM CCS Resource Impact
  - Testing indicates 45% increase in node usage needed by Eta to compress 0-84 hour forecast
  - Projections show this will use maximum amount of CCS resources available to the Eta
    - No additional Eta CCS resources available until at least June, 2004
  - 84-192 hour forecast projected to fit within current 60-84 hour Eta forecast time window
    - Projections based on scaling capabilities of current Eta
    - EMC has completed coding of a CONUS version of the Eta model

Extension of the Eta requires the use of very expensive computing resources

Impacts to NCEP and Customers
(Cont.)

- Minor Impact to EMC Future Development
  - Implementation of WRF infrastructure with NMM and mass core ensemble in Hi-Resolution Window Run delayed from FY04Q4 to FY05Q1 if eight-day Eta implementation requires EMC resources beyond March
  - No impact on GFS upgrade schedule

Impacts to NCEP and Customers
(Cont.)

- Delivery of all 0-84 hour Eta products compressed into smaller time window creating larger network burst
  - Testing indicates earlier delivery times for the 0-84 hour products
    - 24 hour products: 5-10 minutes earlier
    - 36 hour products: 10-15 minutes earlier
    - 48 hour products: 15-20 minutes earlier
    - 60 hour products: 20-25 minutes earlier
    - 84 hour products: 35-40 minutes earlier

Early delivery is a positive, larger network burst is a negative

Impacts to NCEP and Customers
(Cont.)

- New delivery times need to be coordinated with partners and customers
  - Network/System constraints
    - Need to have TOC and SEC investigate if compressed time schedule is problematic to its networks and servers
  - Notification time constraints
    - Minimum 75-day notification lead time required by NWSI 10-1805, National Service and Technical Change Messages
  - Need to assist WFOs quickly without compromising NCEP's relationship with external customers

75 day notification lead time will impact implementation schedule

NCEP Dir agreed to have NCO send notification and start 75-day clock

Model Concerns

- Future model upgrades (Eta, SREF, WRF?) impacted if creation of 84-192 hour Eta segment delayed beyond March, 2004 (EMC involvement)

- Where is the overall concept of operations?
  - Plans being forged to utilize extremely costly supercomputer resources for downscaling without a *visible* plan for end-to-end testing to validate utility of the product and determine if Regional WAN bandwidth can support its reliable delivery

Computing resources are scarce; assurance needed by February that this data stream will actually be used

Regional Delivery Concerns

- Unclear if dataflow path has an appropriate operational management and support structure
  - Change management structure for downscaling and dataflow software being developed in field?
    - Risk of regional adaptations to software
    - Managing future changes to Meso Eta system more complex
  - Efficient 24x7 operational support structure to manage dataflow problems beyond the TOC?
    - NCEP concerned it will have complex troubleshooting support system to navigate when problem calls from the WFO occur
    - WFOs need to clearly understand operational support structure when implemented

AWIPS Concerns

- Different teams within OS&T working various projects involving similar efforts to transfer NCEP data into IFPS
  - Provide ASAP surface data From 12 km Eta out to 84 hours at all cycles and 80km 3-D GFS out to 240 hours for AWIPS OB2
  - By FY04Q4 provide full 12 km 3-D Eta out to 84 hours and full 3-D GFS at all resolutions out to 240 hours for AWIPS OB4
- Key OS&T stakeholders not all aware of this eight-day Eta proposed implementation
  - Could impact implementation process

AWIPS Concerns (Cont.)

- AWIPS software integration needed
  - Is there a national implementation plan based on Western Region software development?
  - Has the AWIPS software delivery schedule factored in needed deliveries?

Other Concerns

- NWS Requirements Process
  - OCWWS involvement not present
    - Not actively solicited by IWT/ISST
  - Path for IWT/ISST recommendations into operations unclear/unknown
  - IWT/ISST establishing national requirements with no OCWWS involvement
  - Product content currently a moving target
    - As of 11/25/2003 telecon [with IWT/ISST leader Brad Colman and OS+T representative Kevin Schrab] product content will grow to include pressure levels above boundary layer

No clear requirement statement as to the number of products, resolution and other characteristics related to the use of the extended Eta by AWIPS/IFPS

Summary

- IWT defined requirement to get WFOs Meso Eta 12 km data to the field to be downscaled to 5 km

- 84-192 hour segment and 12km products need to be developed

- Slight impact to EMC future development

- NWS requirements process not followed
  - Unclear if all regions are On-Board with IWT proposed response ✔ at least 4 of the 6 have

- Priorities and requirements do not look aligned (NCEP/TOC/OS&T/OCWWS)

- Presently, NCEP has low confidence that data can be disseminated reliably to end-user

NCEP Perspective on Status

Requirement	Risk	Probability of Failure	Impact
Model	Future level of EMC involvement unknown	*Low*	Future model upgrade (WRF) impacted if further (unplanned) EMC involvement required
Delivery to TOC	Product requirements uncertain	*Low*	Data volume may increase requiring additional TOC resources
Delivery to Regions and WFOs	Regional WAN bandwidth & support	*Moderate*	Saturation of WAN causes product delivery delays. Regional HQ required to provide 24x7 unfunded technical support
AWIPS	Product requirements uncertain; ingest software not available and tested	*High*	High cost products not effectively meet needs of forecasters or are not effectively delivered for use by forecasters (repeat of Fire-Weather)

DiMego's Perspective

- Jason Tuell said space for 8-day extension likely available on new SBN channel being used to test transition to new DVSB(sp?) together with GRIB2 forms of full Eta-12 and GFS (someone needs to act FAST he said - this is "risk reduction")

- This would satisfy all the major concerns over distribution and delivery through regional WAN's & backdoors

- B U T

DiMego's Perspiration

- NCEP's major concerns over coordination especially at the AWIPS level would remain

- EMC folk can do little or nothing to help resolve this

- Defining requirement for ___ products from 84-192 hr extended range for CONUS area at 06z & 18z and OCONUS areas at 00z & 12z (delivery at current 84 hr delivery time) will go a long way to put things on a firm footing

- Reflect FIELD needs not EMC's grand design

DiMego's Inspiration

- IMHO, much of the NDFD heartburn and embarrassment is related to NDFD's level of detail and implied confidence all the way out to 7-8 days.

- Propose adding to NDFD a single 2-d field of "Confidence Factor" in range (0 to 10 or 100) that reflects overall confidence in forecast. It would vary geographically and with time but not by variable (initially). It would be much higher for days 0-3 than for days 4-8 reflecting proper amount of confidence.

- NCEP would provide guidance grids based on SREF & MREF etc. and forecaster could modify just like all other guidance from NCEP.

Analysis of Record (AoR)

- Forecasters want one (in near real-time)
- NWS/HQ wants one to verify NDFD
- Glahn & Livesey expressed desire for a centrally generated AoR in October 2002 but said there were no resources available
- This and other possible uses / requirements (e.g. Surface Transportation or Local Modeling etc) were enough justification for EMC to start thinking about the problem

EMC's AoR Concept

- Can't just apply simple 2-D analysis to surface data - even though we have tens of thousands of mesonet obs, we have millions of grid-points

- Need a 3-d forecast model to obtain proper solution dictated among observed data, terrain & lower boundary forcing and synoptic forcing

- Propose to apply tried & true NCEP 4-D data assimilation technique of forecast-analysis cycle at high resolution (~2 km) with cost cutting measures to make feasible in production

EMC's AoR Concept

- NCEP's 4DDA will (like the EDAS) use
  - Full complexity of NOAH Land-Surface Model
  - Assimilation of precipitation data
  - To ensure lower-boundary states are optimal
- NCEP will use WRF-NMM as assimilating model to efficiently include
  - Nonhydrostatic effects in the dynamics
  - Terrain following coordinate (hybrid sigma-pressure replaces step-mountain eta)
  - Nudging (not in any of NCEP current models)

EMC's AoR Concept

- Nudge prediction in free atmosphere to an existing solution provided by operational Eta-12 (or the NAM-WRF it will be replaced by in late 2005)
  - Allows focus of 3DVAR on surface where we have majority of truly mesoscale observations
  - Allows use of coarser resolution in vertical (20 vs 60 levels)
- Version of NCEP 3DVAR is being tuned to be primarily 2-dimensional with anisotropic covariance structures that follow the terrain and depend on atmospheric flow and stability

EMC's AoR Cost

- Completion of development and adaptation of an operational AoR code and bullet-proof setup to run within NCEP Operational Suite (~1 FTE very capable)

- AoR would take ~15% of current machine 24 hours a day (absolutely no dillydallying) to do hourly CONUS AoR at 2 km with 6 hour delay (to get Stage III precip): $1.5-2.25M increment to current CCS recurring budget

Background Slides

EMC's Downscaling Concept

- Apply EMC's AoR concept to 25-year North American Regional Reanalysis (2-2.5 FTE+<u>CPU</u>)

- Produce 25 years of 2 km sensible weather grids

- Use with NARR & GR forecasts to produce MOS/NN coefficients for use with NCEP model guidance to produce downscaled results for every gridpoint at every WFO (? FTE – primarily MDL)

  - Produce just NDFD variables (sensible weather)
  - Produce all 3-d variables for high res input to GFE and IFPS which then allow forecaster to add value in producing the actual NDFD fields

Where to Downscale NARR

- Need substantial computer power to produce 2 km downscaled NARR even if done just every 3 hours – might have to settle for 5 km initially.

- NCEP backup machine or "research cluster" are possible sites with enough computer power to consider doing this.

Toth/Lord Downscaling Strategy - A

- Correct model bias (on model grid)
  - Today's forecast vs current model history (1-2 months)
  - Current ensemble mean vs Reanalysis climate mean
- Correct model spread (on model grid)
  - Today's forecast vs current model history
  - Current ensemble spread vs Reanalysis climatological spread
- Apply corrections to all ensemble members
- Result: forecast anomaly on model grid, corrected for climatology
- Calculate most probable anomaly from ensemble (error weighted mean)
- Given high resolution, gridded climatology for each forecast element:
  - Add most probable anomaly to climatology for downscaled forecast element
  - Not guaranteed to be physically consistent (like model grids)
  - Forecast anomaly on model grid needs to be transmitted
  - High resolution climatology resident at WFOs

Toth/Lord Downscaling Strategy – B

- Bias correction directly on NDFD grid
  - High resolution information still needed from local climatology
- Can be done locally or centrally
  - If locally, assumes WFOs receive all ensemble forecast members
- Neural Network application
  - Input: ensemble forecasts, lat, lon, elevation, climatology etc
  - Output: bias corrected ensemble forecasts on NDFD grid
  - Penalty function: probabilistic measure (e.g. Brier Skill Score)